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THE DETECTION THRESHOLD AT THE MONTANA LASA

6 JUNE 1967

Prepared For

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Washington, D. C.

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Under

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THE DETECTION THRESHOLD AT THE MONTANA LASA

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ABSTRACT

Short-period P arrivals on LASA beamformed traces for 56 teleseismic events were used to compute event magnitudes and corresponding threshold magnitudes.

The average event magnitude reported by the USC&GS differed by less than 0.1 from the average magnitude computed at LASA. Threshold magnitudes varied from 3.2 to 4.0; the average, 3.6, is biased downward about 0.1, because of the magnitude factors (B) for deep foci, and an additional 0.1 - 0.2 because only night-recorded events were available for analysis.

1. INTRODUCTION

Early in 1966 several studies were undertaken by the Seismic Data Laboratory in support of the Vela Seismological Center's evaluation of the LARGE APERTURE SEISMIC ARRAY (LASA) in Montana. Since June 1966, reports have been written which relate directly to the detection and identification capability of the LASA system. Included in these reports are three by Chiburis (1966) which describe travel-time anomalies for various epicentral regions, three by Chiburis and Hartenberger (1966) concerning signal-to-noise ratio improvement by beamforming LASA seismograms, and three by Flinn, Hartenberger, and McCowan (1966) which review maximum-likelihood filtering techniques. The analysis of travel-time anomalies has relied upon visual inspection of 16 mm film, whereas the remaining studies have utilized digital seismograms. In all studies to date, we have been concerned only with the P phase and associated band-limited noise.

The present study is an attempt to determine a detection threshold at the LASA for events originating at teleseismic distances. We note that any such magnitude value is highly generalized since it depends not only on the epicentral distance and azimuth, depth of the hypo-center, and the source mechanism, but also on the precision of the beamforming process and the type of prefiltering used. Moreover, it is undoubtedly a function of the recording period. By this we mean that the nighttime noise level is lower than that recorded during the daylight hours, and our detection threshold estimates will be lower than that obtained from a similar set of events recorded during the day. Our basic procedure will be to use LASA beamformed outputs to compute event magnitudes and corresponding threshold values.

Our data are 56 beamformed traces, i.e., phased sums of the subarray phased sums (hereafter referred to as PPA traces) for the teleseismic events shown in Table 1. These events were recorded during the night at the Montana LASA, because of the operational procedure used at that site. Forty-one of these events were discussed in SDL Report Nos. 164 and 173. Events numbered 15 and 53 through 56 are included to test the validity of the theoretical threshold values.

For details regarding the various stages of data processing required to produce beamformed traces, i.e., demultiplexing, detrending, demagnifying, time-shifting, and summing of array and subarray data, the reader is referred to SDL Report No. 164.

2. PROCEDURE

2.1 Signal and Noise

For the purpose of computing event magnitudes, the "signal" is considered to be half the maximum peak-to-trough deflection, in mμ, occuring in the first few seconds of the P signature as it appears on the prefiltered PPA trace. "Noise" is defined as the rms nighttime level achieved on the prefiltered PPA traces for a data sample of 40 seconds before the onset of each signal.

2.2 Minimum Detectable Signal

In order to define the minimum detectable signal (MDS) on the PPA trace, we must first describe the rms background noise field within which the signal will appear. We know from previous analyses that the average measured rms noise level on the PPA traces is $\bar{\sigma} = \pm 0.2$ mμ. If the noise is Gaussian with mean zero and variance $\bar{\sigma}^2$, 95% of the noise amplitudes on the beamformed

EVENT	m C & GS	m_1	m_0		EVENT	m C & GS	m_1	m_0
1.	4.1	4.3	3.4		29.	3.9	4.1	3.3
2.	4.3	4.4	3.5		30.	5.0	5.0	3.6
3.	4.3	4.3	3.4		31.	4.9	4.8	3.2
4.	5.7	5.7	3.4		32.	5.2	5.6	3.5
5.	5.2	5.0	3.8		33.	5.1	5.2	3.6
6.	5.1	5.4	3.6		34.	4.1	4.2	3.2
7.	5.1	4.9	3.7		35.	4.4	4.6	3.6
8.	4.7	4.6	3.7		36.	5.6	5.3	3.9
9.	4.7	5.1	3.6		37.	4.8	5.0	3.6
10.	4.9	4.6	3.5		38.	6.0	5.5	3.7
11.	5.0	4.8	3.6		39.	4.6	4.9	3.8
12.	5.1	5.0	3.7		40.	6.3	6.1	3.9
13.	5.2	5.6	3.8		41.	4.8	5.3	3.7
14.	4.5	4.8	3.8		42.	5.8	5.8	3.8
15.	*3.9	3.9	3.7		43.	6.3	6.3	3.9
16.	3.9	4.1	3.3		44.	*5.8	6.2	3.8
17.	4.9	5.0	3.2		45.	4.9	4.9	3.9
18.	4.8	4.7	3.2		46.	5.5	5.6	3.8
19.	4.9	4.7	3.4		47.	5.7	5.5	3.8
20.	5.3	5.4	3.3		48.	4.8	4.6	3.8
21.	4.3	4.6	3.4		49.	5.0	5.1	3.7
22.	5.0	5.5	3.5		50.	5.2	5.6	3.9
23.	4.5	4.3	3.5		51.	4.8	4.8	3.3
24.	4.9	4.7	3.5		52.	*3.9	4.3	3.9
25.	4.3	4.5	3.7		53.	*4.8	5.3	4.0
26.	4.6	3.9	3.4		54.	*3.7	3.9	3.3
27.	3.8	4.3	3.3		55.	*3.3	3.4	3.4
28.	4.6	4.9	3.7		56.	*4.0	-	-
					AVERAGES	4.91	4.96	3.6

*NON C & GS MAGNITUDE (Not included in average)

Table 1. Event Magnitudes

traces would be expected to lie in the interval $0 \pm 2\bar{\sigma} = 0 \pm 0.4$ mμ. This means that about one noise cycle in twenty should exceed ± 0.4 mμ, and that signals which are greater than or equal to 0.4 mμ, would be larger than 95% of the noise amplitudes. Moreover, the amplitude interval which includes 99% of the noise would be $0 \pm 3\bar{\sigma} = 0 \pm 0.6$ mμ and signals ≥ 0.6 mμ would be larger than the background noise level 99% of the time. If we assume an MDS amplitude on the PPA trace equal to ± 0.6 mμ, we must input an average signal amplitude of ± 0.8 mμ, because of signal losses accompanying the beamforming process.

2.3 Magnitude Determinations

LASA magnitude (m_1) for each event was computed in the following manner:

$$m_1 = \log A_{PPA}/T_{PPA} + \beta$$

where A_{PPA} = signal amplitude from the PPA trace,
T_{PPA} = signal period from the PPA trace,
β = magnitude factor for distance and depth.

The threshold magnitude (m_0) for each event was determined using the following relationship:

$$m_0 = m_1 - \log X$$

in which $X = A_{PPA}/MDS = A_{PPA}/0.8$

3. RESULTS

Table 2 of SDL Report No. 164 lists the rms noise levels achieved on 41 LASA beamformed traces filtered 0.4 - 3.0 cps. These values form the basis for Figure 1 in this report which shows the probability that seismic noise will be less than a given amplitude on a beamformed trace. As shown in Figure 1, the probability that the noise level will be less than 0.2 mμ is 0.5;

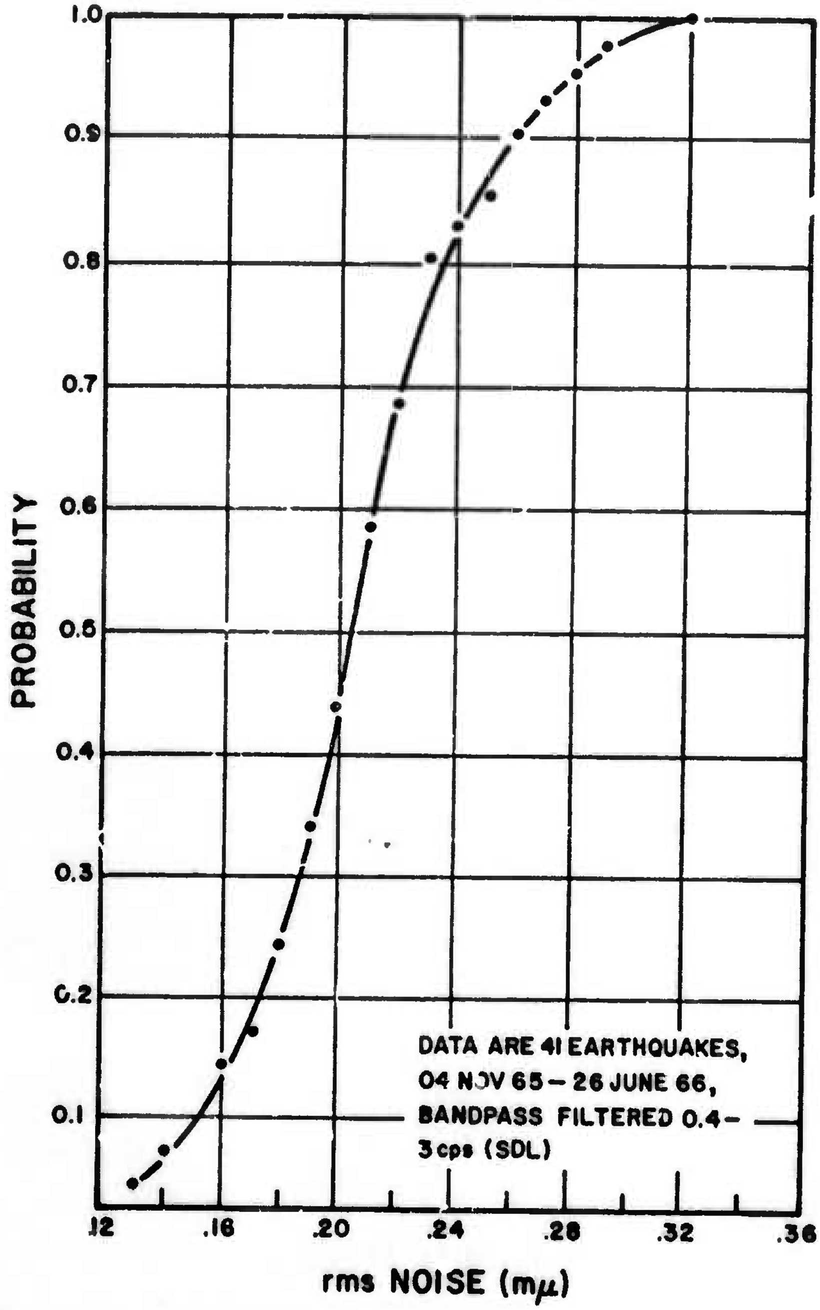

Figure 1. Probability that noise will be less than a given amplitude on a LASA beamformed output trace

this is the value reported by Romney (1966) which was based on the analysis of 19 teleseismic events recorded at the Montana LASA. Figure 2 illustrates the log normal distribution of the same 41 noise values.

Table 1 summarizes the results of this analysis and shows C&GS magnitude, LASA Magnitude, LASA threshold magnitude, and averages for the 56 events analyzed to date. These data illustrate two important points. First, the average C&GS magnitude differs from the average LASA magnitude by less than 0.1, even though LASA computations were based on data taken from beamformed output traces. Figure 3 further illustrates this point. Second, threshold magnitudes vary from 3.2 to 4.0 and average 3.6: this magnitude, 3.6, represents our estimate of the overall detection capability of the Montana LASA if the array is beamed precisely at the source, and if the distance distribution of events correctly samples the teleseismic zone. It will be lower than the threshold computed for bombs or shallow quakes, since the magnitude corrections which were applied for deep events bias the threshold downward about 0.1. It will furthermore be lower than a magnitude based on daytime recordings. Beamformed seismograms for five relatively small teleseismic events are shown in Figure 4. First arrivals are plainly visible on four of the five traces; in the case of the magnitude 4.0 event, however, the beamforming and filtering processes failed to produce a recognizable P signature. The output trace second from the top of Figure 4 is particularly interesting because the LASA magnitude and the threshold magnitude are the same, 3.4.

4. CONCLUSIONS

The following conclusions are based on a study of beamformed outputs (filtered 0.4 - 3.0 cps) for 56 teleseismic events recorded

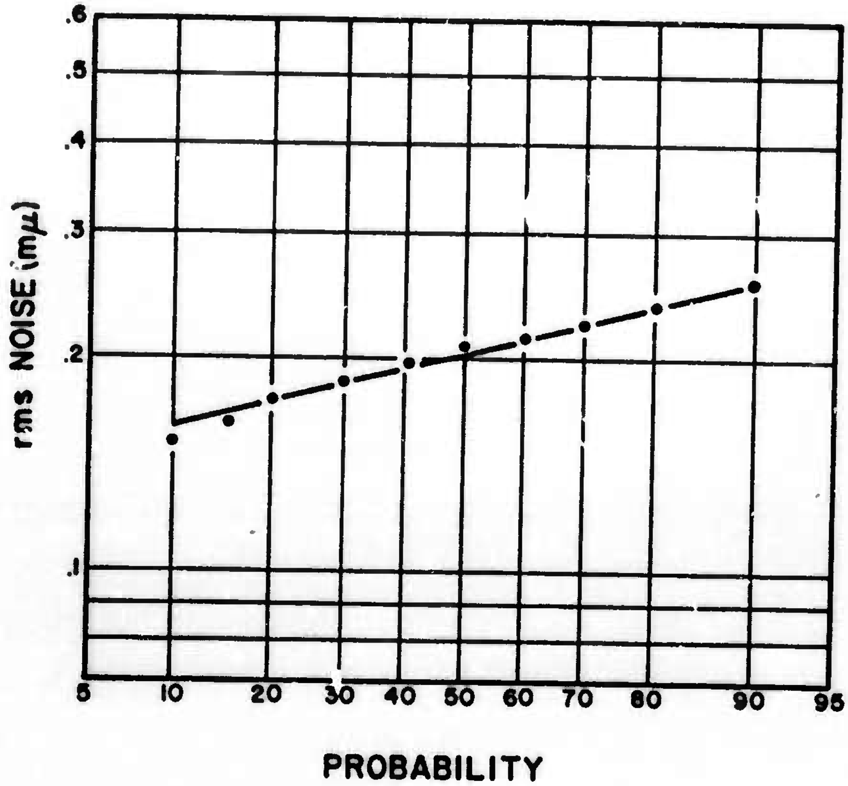

Figure 2. Probability that noise on a LASA beamformed trace will be less than a given amplitude

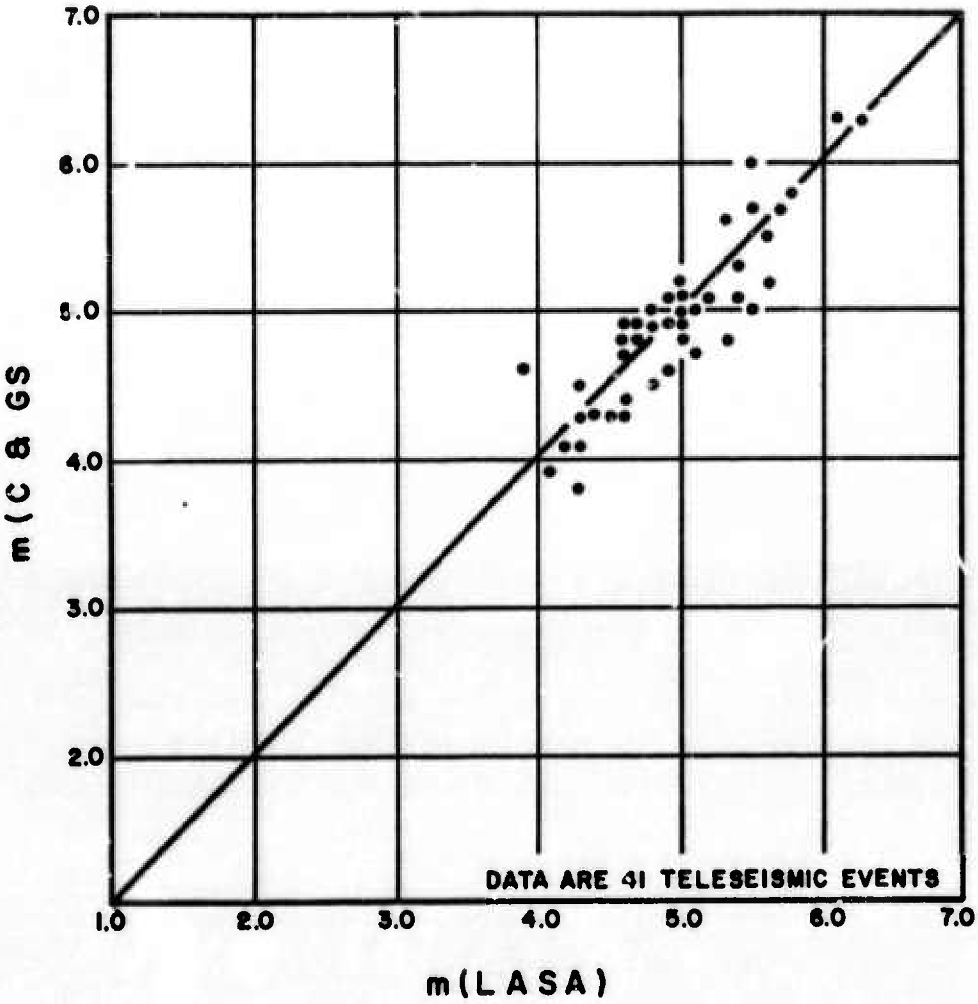

Figure 3. Magnitude comparisons

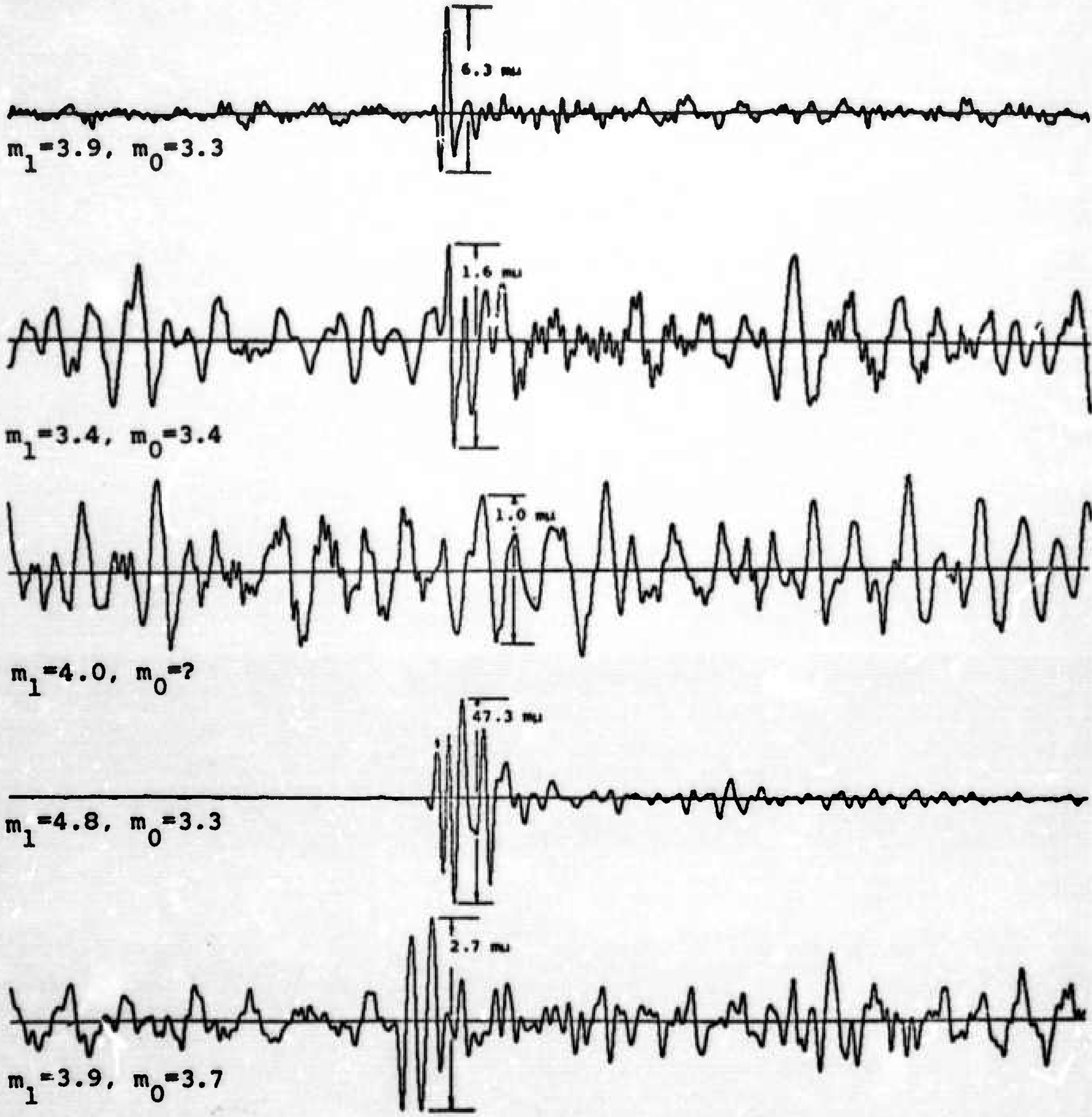

Figure 4. LASA beamford seismograms

during the night at the Montana LASA in the period November 1965 to June 1966:

1. LASA magnitudes based on data taken from the beamformed traces differ from those computed by the USC&GS by less than 0.1.

2. The Montana LASA should be able to detect a mixture of shallow and deep events of average magnitude 3.6 as a result of the beamforming process. For bombs and shallow quakes, the threshold would be 0.1 higher because of the correction factor for deep foci. For daytime recordings we estimate that it would be an additional 0.1 - 0.2 higher because of higher noise levels. Obviously, this magnitude, 3.6, is highly generalized since it is a function of several parameters which include epicentral distance and azimuth, source mechanism, beamforming precision, and type of bandpass filter used.

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